Flexibility demand in long–term energy scenarios in the U.S.

First results of a case study for New England

11th International Renewable Energy Storage Conference (IRES)

Düsseldorf, 03/15/2017

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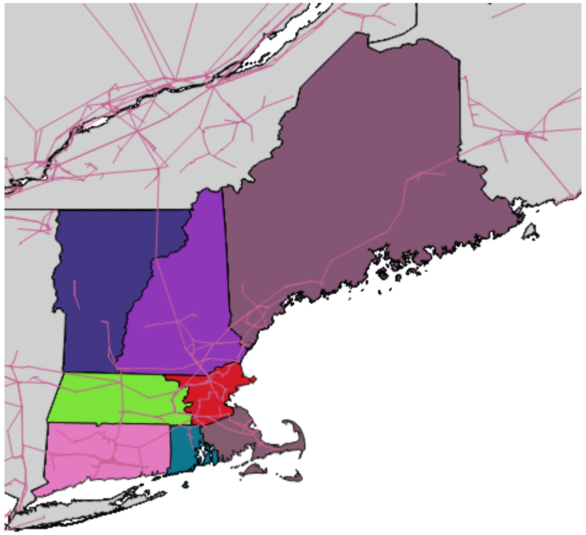
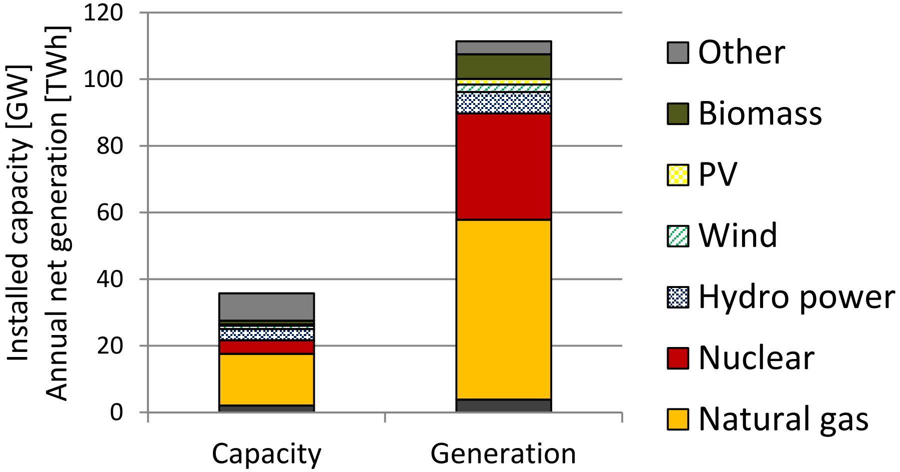
Overview ISO New England

Generation and capacities (2015)



- Peak load 24 GW
  - Connecticut: 6 GW
  - Boston area: 5 GW
- Power demand 125 TWh/a
  - Connecticut: 31 TWh/a
  - Boston area: 25 TWh/a
- Generation heavily relying on natural gas and nuclear power generation
  - Natural gas: 54 TWh/a
  - Nuclear: 32 TWh/a
- Transmission inter-connectors to New York and Canada



Sources:

[1] U.S. EIA, “2015 Form EIA-860 Data - Schedule 3, ’Generator Data’ (Operable Units Only), [Dataset],” 2015.
[2] U.S. EIA, “2015 Form EIA-860 Data - Schedule 3, ’Net Generation by Energy Source’, [Dataset],” 2015.

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Research questions and main assumptions (I)

Research questions

- Is a highly renewable energy system (heat & power) for New England feasible?
- What is the role of flexibility options?
- How important is the coupling of the power and heat sector?

Main assumptions

- Partial greenfield capacity expansion[1] and dispatch optimization (least costs) with the REMix model (**R**enewable **E**nergy **Mix**)
- Constraint forces at least 25% of a model regions electricity demand is supplied by local resources
- Investment options into generation technologies and flexibility options
  - On/offshore wind, PV, gas turbines
  - H_2 storage, stationary Li-ion batteries, PHS (only pump/turbine exp.), grid expansion

[1] Existing hydro-power plants are included

Main assumptions (II)

Technologies

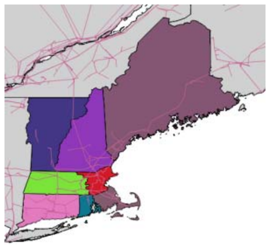
Storage

Storage	Modeling	Scenario
H_2 (power-H_2-power) Stationary Li-ion batteries Pumped hydro (1) 	▪ Charge/discharge efficiency ▪ Self discharge rate ▪ Availability ▪ CAPEX converter (charge/discharge) & storage ▪ Lifetime (economic + technical) ▪ O&M costs (fix/var.)	▪ H_2 in salt caverns & power reconversion ▪ Model endogenous capacity expansion including expansion limits for all storage technologies

Renewables

Renewables	Modeling	Scenario
Wind on/offshore Photovoltaic Hydro power 	▪ Efficiencies (part. temp.-dependent) ▪ CAPEX ▪ Availability ▪ Lifetime (economic + technical) ▪ O&M costs (fix/var.)	▪ Model endogenous capacity expansion ▪ Expansion limits based on resource assessment ▪ Unlimited curtailments ▪ Consideration of exiting hydro caps

Transmission grid

Transmission grid	Modeling	Scenario
AC 	▪ DC approximation of 3 phase AC ▪ CAPEX ▪ Grid losses	▪ Greenfield ▪ Existing based on SciGrid data (2) ▪ Unrestricted capacity expansion

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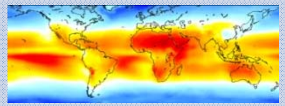
(1) "Accupack 10 cellen side by side" by Accu4all - Own work. Licensed under CC BY-SA 3.0 via Wikimedia Commons - https://commons.wikimedia.org/wiki/File:Accupack_10_cellen_side_by_side.png#/media/File:Accupack_10_cellen_side_by_side.png

(2) C. Matke, W. Medjroubi, and D. Kleinhans, SciGRID - An Open Source Reference Model for the European Transmission Network (v0.2), www.scigrid.de, 2015

REMix (Renewable Energy Mix)

Input

RE Potentials 

Demand profiles (Power, Heat, …) 

Installed power plants

OPEX, CAPEX

Grid 

Mathematical Optimization

Minimization of system costs

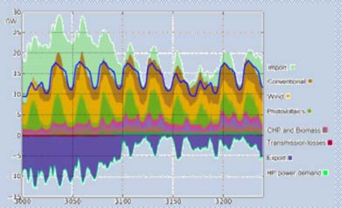
Min/Max $\sum_{j \in n} c_j x_j$

Consideration of technical restrictions

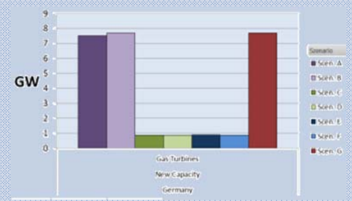
$\sum_{j \in n} a_{ij} x_j \geq b_i \quad , \forall i \in 1 \ldots m \qquad x_j \geq 0$

Output

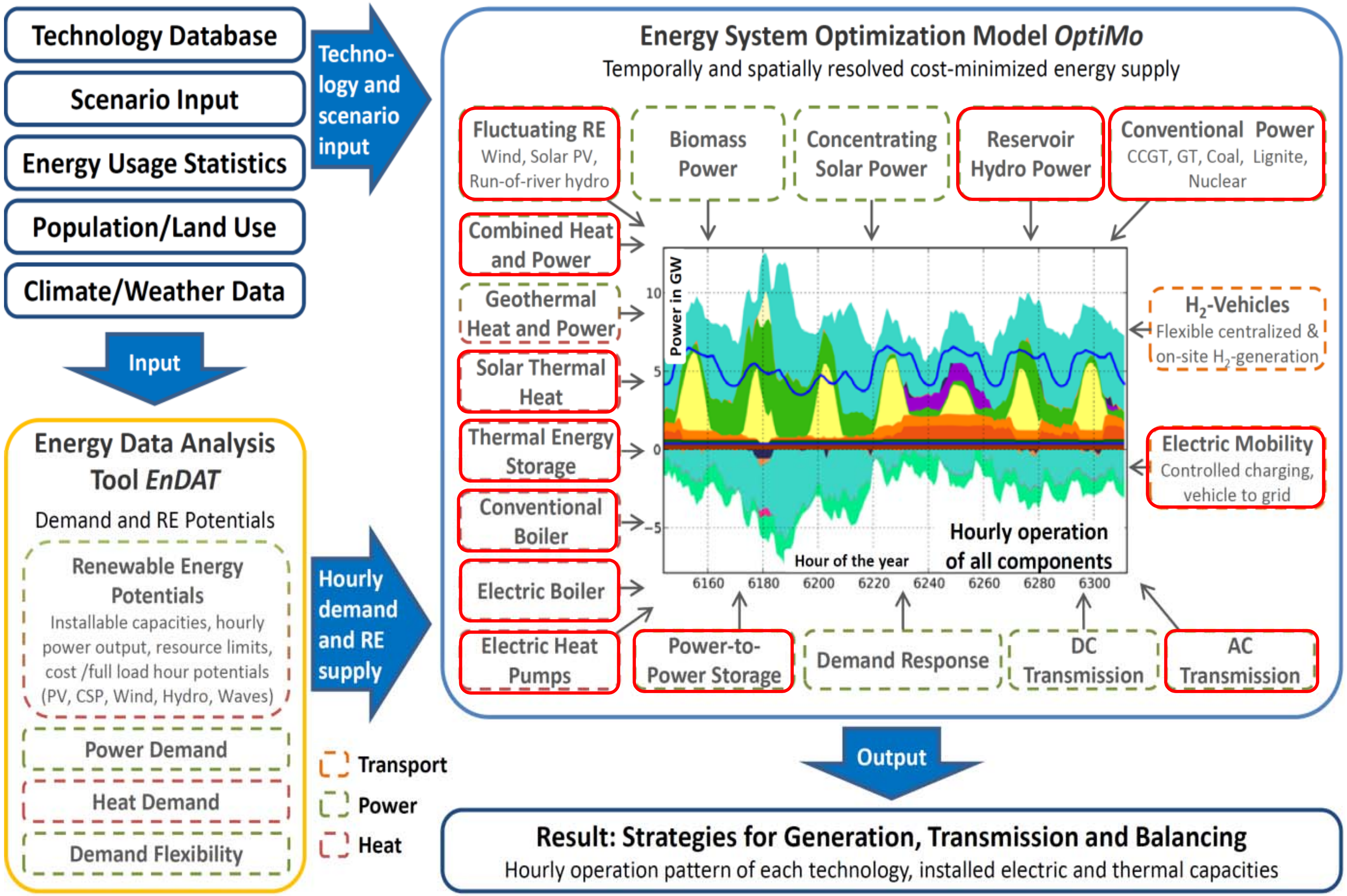
Technology commitment (utilization)



Capacity expansion (storage, transmission lines, power plants)



REMix model structure



Scenario definition

1. Reference scenario (curtailment, existing grid)
2. Scenario Flex +
3. Scenario Flex ++
4. Scenario Flex +++
5. Scenario Flex ++++

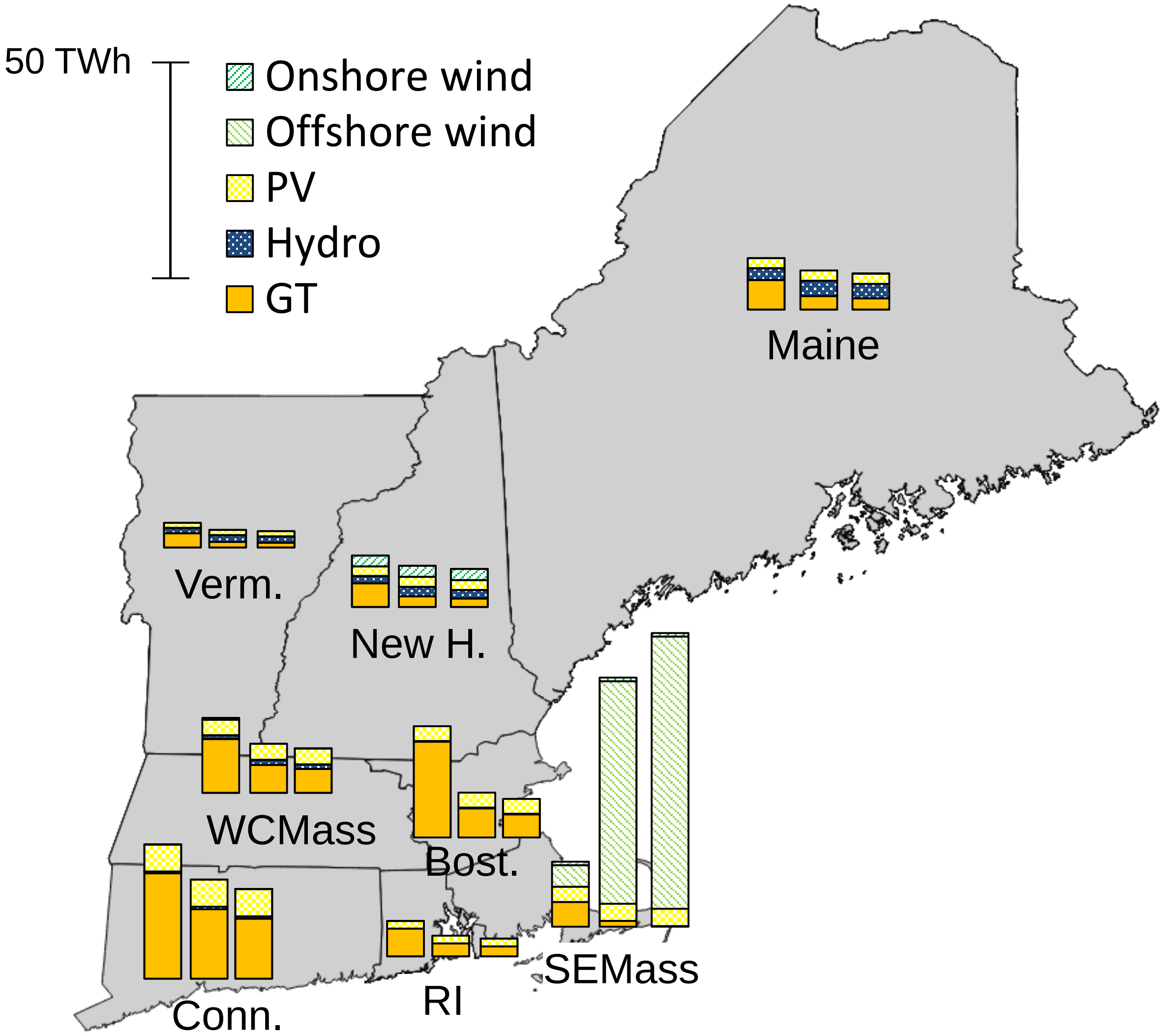
+ Grid exp.

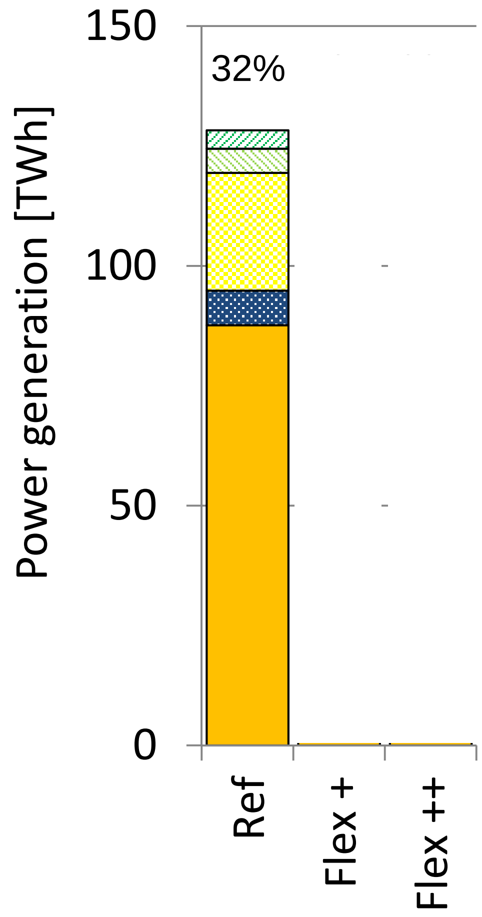
+ Grid exp.
+ Storage

+ Grid exp.
+ Storage
+ cBEV

+ Grid exp.
+ Storage
+ cBEV
+ sector coupling (power<>heat)

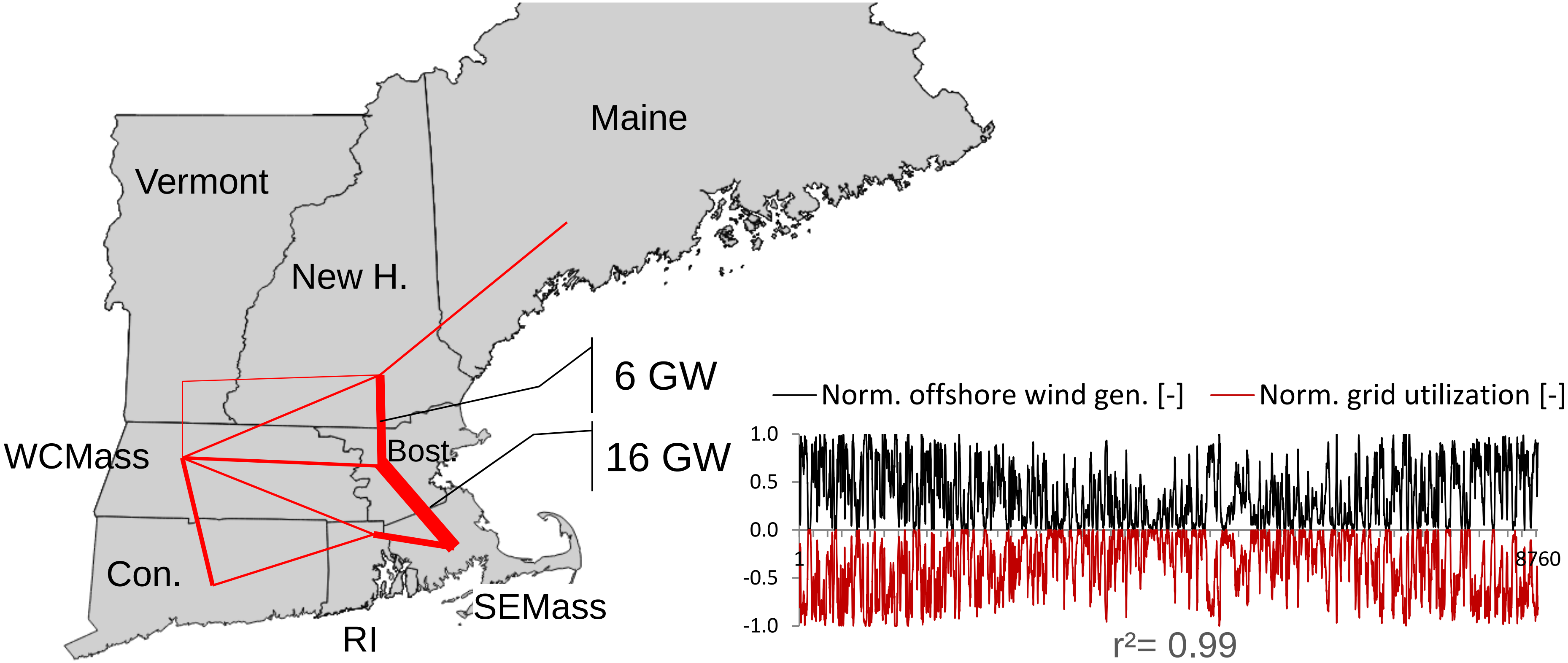
Annual power generation





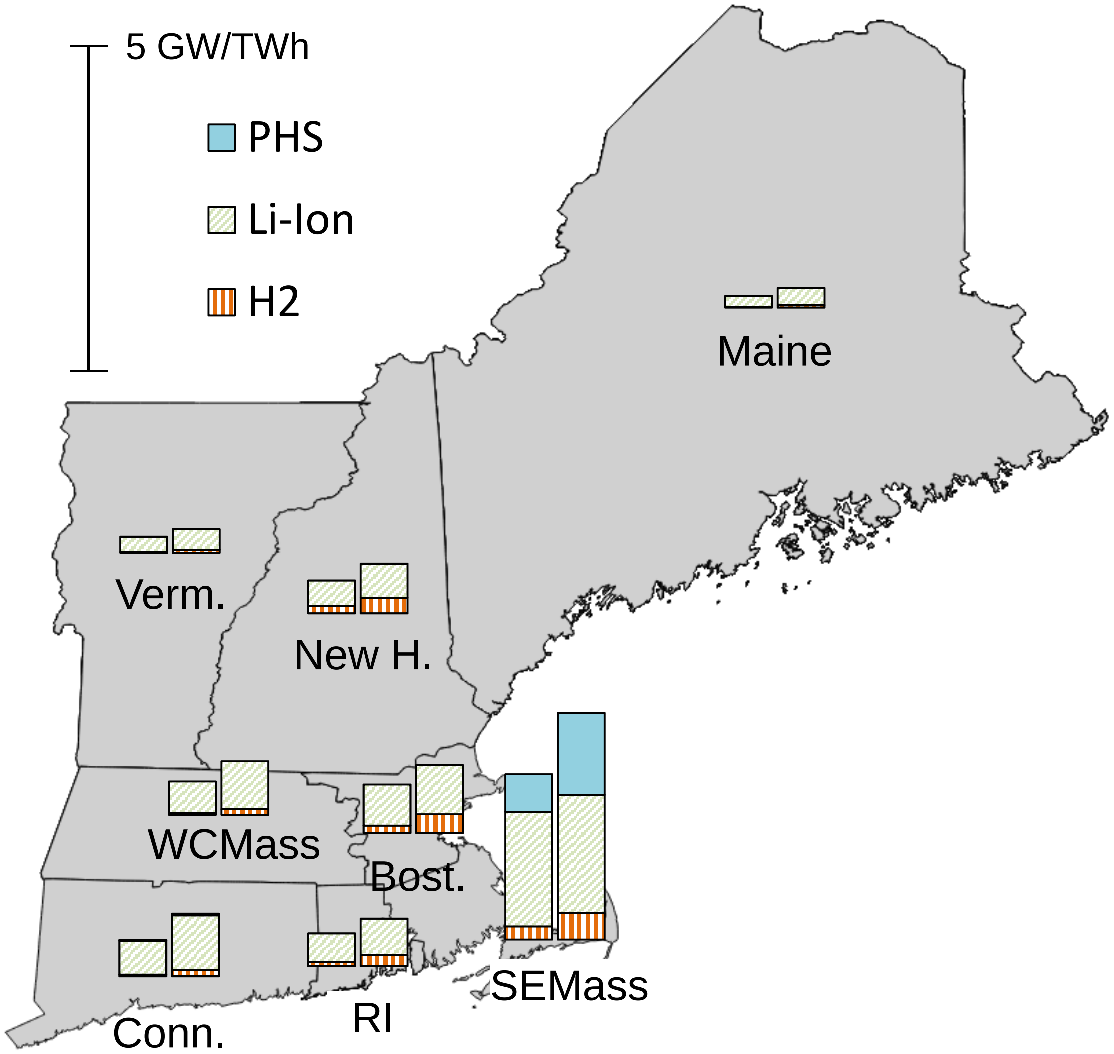
AC grid expansion (scenario Flex +)

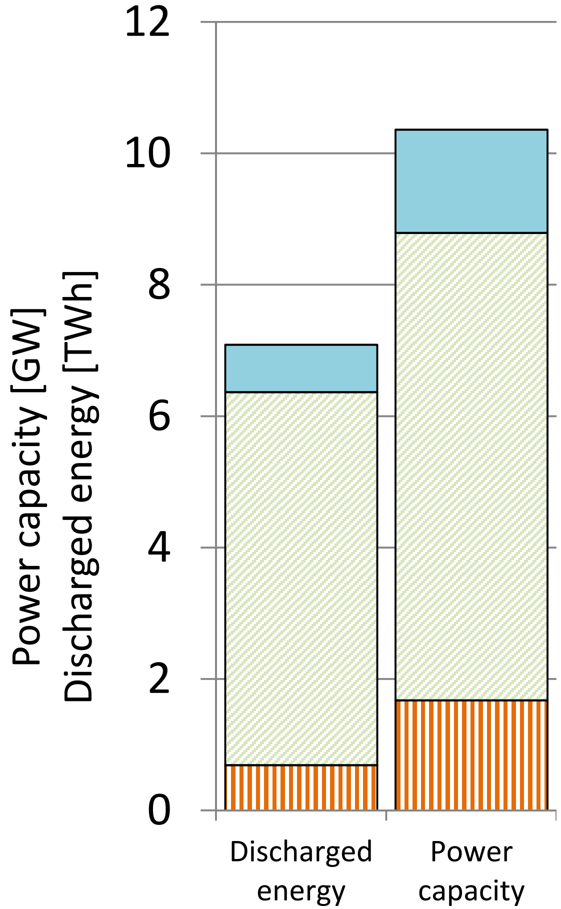
- Capacity expansion: 39 GW, net import/export: 43 TWh



- Grid expansion to connect regions of large RE potential (SEMass) to regions of high demand (Boston area)

Storage capacity





Conclusion & further research

First key results

- Power generation is dominated by offshore wind of the region south-east Massachusetts
- Spatial balancing through grid allows increased RE integration by 41% (from 32% to 73%), substituting ~10 GW of gas turbines
- Further temporal balancing through power storage enables a RE share as high as 80% and reduces curtailments
  - Flex+ = 8.3 TWh/a (~6% of VRE generation, mainly offshore w.)
  - Flex++ = 3.7 TWh/a (~3% of VRE generation, mainly offshore w.)

Ongoing research and open questions

- Coupling to the heat sector
- Test influence of inter-connector to New York and Canada
- Sensitivity analysis: cost variations, expansion limits

Thank you!

Questions?

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